malleable to some extent, but breaks off short when nicked with the chisel and then bent. Looks homogeneous.

Analysis gave:

$$\begin{aligned} Pb &= 96.10 \\ As &= \ \ 3.75 \\ \hline & \ \ 99.85 \end{aligned}$$

$$Pb : As = 0.4637 : 0.050 = 9.27 : 1$$

The ratio is that of whitneyite. The ionic mobility is small.

MICHIGAN COLLEGE OF MINES, May, 1903.

CRYSTALLOGRAPHIC PROPERTIES.

BY FRED EUGENE WRIGHT.

The following group of artificial minerals, which Dr. Koenig has kindly intrusted to me for crystallographic investigation, is characterized by high metallic luster, tin-white to steel-gray and even black color, conchoidal fracture and hardness : 3–4. The crystals obtained are all small and rarely exceed a millimeter in length. The character and quality of the crystal faces is not uniform for the whole group. Those of domeykite are usually sharp, well formed and furnished single reflection signals on the goniometer, whereby a fairly exact determination of its elements could be obtained. The crystals of the remaining minerals are far less perfect, their uneven undulating faces evincing such indistinct, manifold reflexion signals on the goniometer that an accurate determination of their elements was impossible.

The crystals were measured on a Goldschmidt's two-circled goniometer (model 1901), with attachment for observing small, weak faces and an electric arc goniometer lamp.[1]

[1] The electric goniometer lamp (Fig. A) consists of a box (*a*) made of Russian sheet iron, lined with asbestos cardboard, and of an electric lamp (*b*). The back of the box (*a*) is left open to allow the insertion of the electric lamp—a small black movable curtain serving to shut off all false light, which might disturb in measuring. The mirror (*d*) and cap (*e*) are used to light the verniers and were taken bodily from a Goldschmidt's Auer burner gas goniometer lamp (see *Zeitschrift für Krystallographie*, Bd. xxiii, 1894, p. 149. V. Goldschmidt. Eine neue Goniometer-lampe). The electric lamp (*b*) is the No. 10, hand feed, of J. B. Colt & Co., Chicago, Ill. (price, $10), together with an adjustable rheostat (seven to eighteen ampères, $13). By means of the latter the intensity

DOMEYKITE.

Twelve domeykite crystals were measured, all of which indicated the holohedral division of the hexagonal system with the following observed forms :

Letter:	*c*	*b*	*a*	*z*	*v*	*p*	*x*
Symbol Bravais	0001	$10\bar{1}0$	$11\bar{2}0$	$20\bar{2}3$	$10\bar{1}1$	$20\bar{2}1$	$11\bar{2}2$
Goldschmidt....	0	$\infty 0$	∞	$\frac{2}{3}0$	1 0	2 0	$\frac{1}{2}$

Also two uncertain forms ? $\frac{1}{6}$ 0 ($10\bar{1}6$), which occurred only once

---

of the light may be regulated. An ammeter may be used, but is hardly necessary. In the slits in the tube (*f*) two small colored (blue and green) pieces of glass are placed, which cut down the intensity of the light and impart to it a color restful to the eye. In case very bright light is needed one of the glass plates

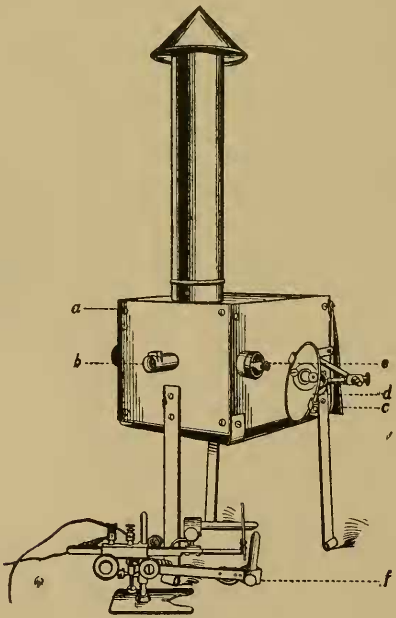

Fig. A.

may be removed. The carbons are observed through a round piece of glass fitted in the cap (*e*). The electric arc goniometer lamp is especially adapted for the measurement of etch figures and minute crystal faces, but serves equally well for ordinary measurements as the light intensity may be regulated and cut down at will.

as a sharp, perhaps vicinal face on crystal No. 4; and? $\frac{1}{2}$ 1 ($12\bar{3}2$), observed once as a small rounded face (crystal No. 3).

Element: $p_0 = 1.0259 \pm 0.0006$
$a : c_{10} = 1 : 0.8885$ [1]
$a : c_1 = 1 : 1.539$

The element p_0 was calculated from the mean of the angles of 27 sharp, single reflecting pyramidal faces of the measured crystals, no attempt being made to separate the different types of crystal habit. The form *v*, 10 furnished 12 of these faces ($\varphi = 30° 00'$, $\rho = 45° 44'$, possible error $\pm$ 1′), the form *p*, 20, 11 faces ($\varphi = 30° 00'$, $\rho = 64° 01'$, possible error $\pm$ 3′), and the form *z*, $\frac{2}{3}$ 0, 4 faces ($= 30° 00'$, $\rho = 34° 23'$, possible error $\pm$ 1′).

Table of Angles.[2]

c=1′539	lg c=018721	lg a_0=005135	lg p_0=001112	a_0=1′1255	p_0=1′0259	(G_1)

No.	*Letter*	*Symbol*	*Bravais*	ϕ	ρ	ξ_0	η_0	ξ	η	x (*Prisms*) ($x : y$)	y	$d = tg\ \rho$
				°	°	°	°	°	°			
1	*c*	0	0001	—	0.00	0.00	0.00	0.00	0.00	0	0	0
2	? *a*	∞	$11\bar{2}0$	30.00	90.00	90.00	90.00	30.00	60.00	0′.5773	∞	∞
3	*b*	∞ 0	$10\bar{1}0$	0.00	90.00	0.00	90.00	0.00	90.00	0	∞	∞
4	*z*	$\frac{2}{3}$ 0	$20\bar{2}3$	0.00	34.23	0.00	34.23	0.00	34.23	0	0′.6840	0′.6840
5	*v*	1 0	$10\bar{1}1$	0.00	45.44	0.00	45.44	0.00	45.44	0	1′.0259	1′.0259
6	*p*	2 0	$20\bar{2}1$	0.00	64.01	0.00	64.01	0.00	64.01	0	2′.0518	2′.0518
7	? *x*	$\frac{1}{2}$	$11\bar{2}2$	30.00	41.37	23.57	37.34	19.23	35.06	0′.4443	0′.7730	0′.8885

Description of the Individual Forms.

1. The form *c*, 0 (0001) was absent on only one crystal (No. 9, Fig. 4). It has sharp hexagonal outline, splendent metallic luster and is usually perfectly flat, except in the larger crystals where it is frequently uneven and undulating. If observed under a micro-

[1] $a : c_{10}$ denotes the axial relation of the pyramid 10 ($10\bar{1}1$) and $a : c_1$ those of the pyramid 1 ($11\bar{2}1$). See V. Goldschmidt, *Index der Krystalformen*, Vol. i, p. 35.

[2] Calculated according to scheme given in *Winkeltabellen*, von V. Goldschmidt.

scope lighted by auto-colimation the basal plane frequently appears covered with three systems of fine lines, cutting one another at an angle of 60° and running parallel to the outer edges of the crystal. The striæ are usually so fine that they are invisible to the naked eye and have no effect on the sharp reflexion signal from the face.

2. The form *a*, ∞ $(11\bar{2}0)$ is rare, occurring but once on one crystal, and then somewhat rounded. From the correct position of the reflexion signal, however, the character of the zone and relations

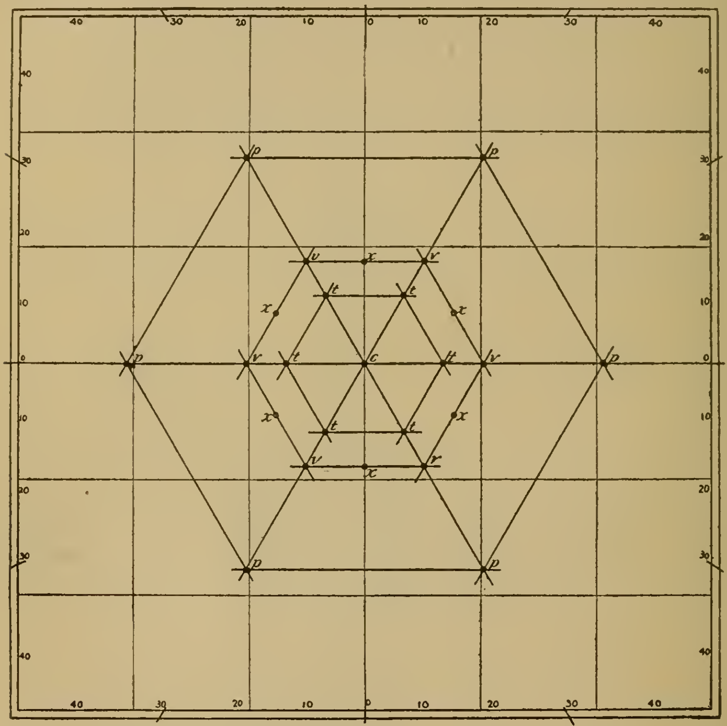

Fig. 1.

to the other faces, the form was considered probable. Its position on the crystal is given in Fig. 4.

3. The form *b* $(10\bar{1}0)$, ∞ o was observed on ten of the twelve measured crystals, often perfectly even and flat, at times, however, striated parallel to the basal edge—a phenomenon especially noticeable on the hollow skeleton-like crystals (Fig. 3), and due probably to the imperfect formation of the face.

The character of the three pyramidal faces *z*, *v*, *p*, is uniform and unvaried. Long narrow faces exhiting occasionally fine striæ parallel to the basal edge, particularly on the hollow crystals. The form *z*, $\frac{2}{3}$ 0 (20$\bar{2}$3) appeared on three of the measured crys-

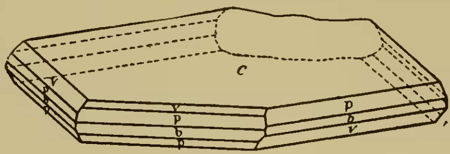

Fig. 2.

tals, *v*, 10 (10$\bar{1}$1) on ten, and the form *p*, 20 (20$\bar{2}$1) on ten and on one crystal as the only pyramid (Fig. 5).

The form *x*, $\frac{1}{2}$ (11$\bar{2}$2), like *a*, ∞ 0, occurred but once and on the same crystal with the latter, as a small rounded face (Fig. 4).

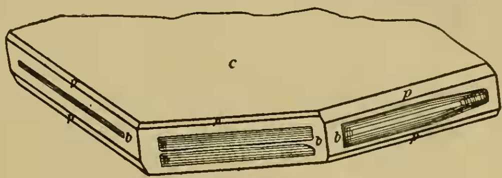

Fig. 3.

Its reflexion signal was approximately in its correct position. The form is considered probable.

Fig. 1 gives a gnomonic projection of all the observed forms on domeykite.

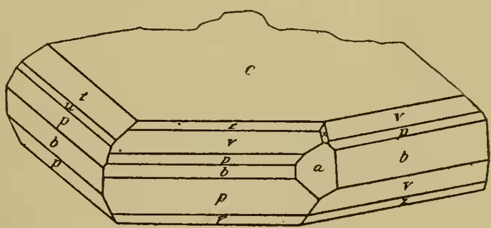

Fig. 4.

Types of Crystal Habit.—Fig. 2 (crystal No 1, dimensions 1.2 × 1.2 × 0.3 mm.) illustrates the first and most common type of domeykite crystals. Flat, thin tabular cystals with the forms 0, ∞ 0, 10, 20, the last three as narrow, sharp faces frequently striated horizontally. These artificial crystals are occasionally hollow and resemble then Fig. 3 (crystal No. 8, 1.1 × 1.0 × 0.4 mm.). The central part of the prism faces is not filled out as yet, while the basal plane is perfectly flat, although in some cases a mere fragile paper-like film. The pyramid faces are usually present in the form of narrow strips. The hollow parts of the crystals seem to consist of a pile of innumerable thin plates piled one on top of the other, similar to the structure of a biotite crystal. The first type passes gradually into a thicker tabular one, in which the pyramid faces are more prominent. Fig. 4 (crystal No. 5, 0.9 × 0.9 × 0.5 mm.). In one case the steep pyramid *p*, 20,

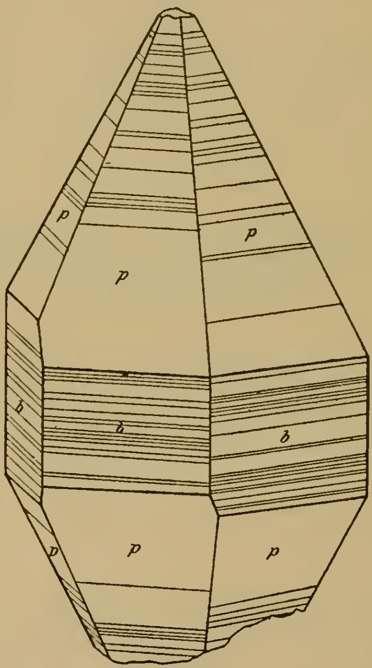

Fig. 5.

with *b*, $\underset{\smile}{\infty}$ o, were the only faces developed. Fig. 5 (crystal No. 9, 1 × 0.5 × 0.6 mm.). Fine horizontal striæ were then apparent on all faces of the crystal. Rounded transitional faces between *v* and *c* were noticed on one crystal.

Of the measured crystals No. 1 (with the observed forms *c*, *v*, *p*, *b*), No. 7 (with *c*, *v*, *p*, *b*), No. 10 (with *c*, *v*, *p*, *b*), No. 12 (with *c*, *v*, *p*, *b*) belonged to the first type of crystal habit; No. 8 (with *c*, *p*, *b*) to the second; No. 2 (with *c*, *z*, *v*, *b*), No. 3 (with *c*, *v*, *p*, *b*), No. 4 (*c*, *v*, *b*, $\frac{1}{6}$, 0 (?)) No. 5 (*c*, *z*, *v*, *p*, *a*, *b*, *x*), No. 6 (*c*, *z*, *v*, *p*, *b*) and No. 11 (*c*, *v*, *p*) to the third, and No. 9 (with *p*, *b*) to the fourth.

Development of the Crystal Forms.—The only zone of any consequence present is that of the pyramid from the base to the prism. Considering the base and prism as primary forces the series reads *c*, *z*, *v*, *p*, *b* or 0 $\frac{2}{3}$ 1 2 ∞. This series is normal except for the second member $\frac{2}{3}$. The sense of this variation is not apparent. The primary forces have produced in the domeykite crystals the most common crystal faces. The simple dominant of the series *v*, 10, and the form *p*, 20, appear equally well developed, while the most highly differentiated form *z*, $\frac{2}{3}$ 0 occurs least frequently.

The crystals of domeykite tarnish easily to iridescence, and are then unfit for measurement. Luster of fresh crystals splendent metallic; color tin-white to steel-gray in reflected light, black in diffused light, often with a tinge of red. Fracture conchoidal, uneven. Brittle. Indications of a cleavage or parting after the base may result from the leafy texture mentioned above. Cleavage after the prism *a* (11$\bar{2}$0)) ∞ imperfect but distinctly noticeable. The specific gravity was left undetermined, as sufficient material for an accurate measurement was not available.

Etch Figures.

In these experiments the etch figures on the basal plane only were observed. This face is the largest and most perfect, and the one best adapted to reveal the crystallographic nature of the mineral. The other faces, moreover, occur only as narrow bands, frequently striated horizontally—two features detrimental to the formation of good etch figures.

In the process of etching, the minute domeykite crystals were placed in a small receptacle or holder made of finely woven platinum wire meshes, attached to which was a long handle of thicker wire, and then dipped into the acid, allowed to remain there a certain length of time, finally removed by means of the thick wire handle and plunged quickly into water. In this manner it was pos-

[1] Compare V. Goldschmidt, "Ueber Entwickelung der Krystallformen," *Zeitschrift für Krystallographie*, Bd. xxviii, p. 1–35, 419–451.

sible to measure the time of attack or exposition of the acid exactly to a second.

Etching acids used were NO_3H and HCl. The action of these two acids on the domeykite crystals is totally different. The nitric acid works energetically and causes a strong development of gas which keeps the submerged crystal in constant motion. The hydrochloric acid in contrast attacks the crystals very slowly (even when heated), causes no gas bubbles but becomes gradually colored yellow.

Nitric Acid.—With this acid the best results were obtained with a cold (15° C.) dilute solution of four parts concentrated nitric acid (70.6 %, sp. gr. = 1.426) and five parts water, with time of exposition 10″–20″. On one crystal unusually sharp etch figures were observed after an exposition of 13″. A long series of different concentrations were tried (from concentrated NO_3H down to 1 : 2 and lower). The times exposed varied from 10″ up to 120″. Nitric acid appears to etch most rapidly parallel to the outer edges of the crystal. The etch figures are very small, remarkably flat and shallow; exhibit generally sharp hexagonal outline, and grade especially on too long exposition or too concentrated acid into a hexagonal network of three systems of straight lines running parallel to the outer edges of the crystal. Compare the following figures:

Fig. 9	(dilution	4 : 5.	Time of exposition	30″.	Magnification 40 ×).
Fig. 10	"	4 : 5.	" "	20″.	" 60 ×).
Fig. 11	"	4 : 5.	" "	40″.	" 40 ×).
Fig. 12	"	3 : 4.	" "	60″.	" 60 ×).

On one crystal, however, three-sided figures were observed, their slightly convex lines running parallel to the outer edges of the crystal. On several crystals one of the three systems of lines appeared in certain parts of the field to be less strongly developed than the remaining two sets, while in other parts of the field a second system was absent, etc. (Fig. 11). The rule seems to hold good in such cases that in the near vicinity of an outer edge that system of lines is poorly developed which runs parallel to the edge. The outer edge seems to have had a certain influence on the development of the lines of the etch figures. Usually, however, all three sets of lines are equally well formed (Fig. 12). The etch figures are so small that they give no noticeable reflexion signals on the goniometer.

Hydrochloric Acid.—Hydrochloric acid attacks domeykite under

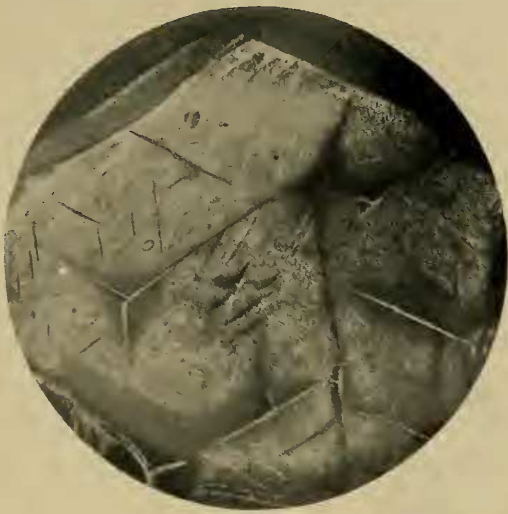

FIG. 9.

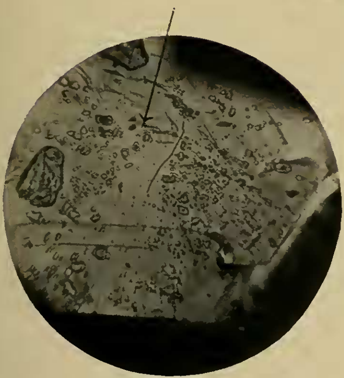

FIG. 10.

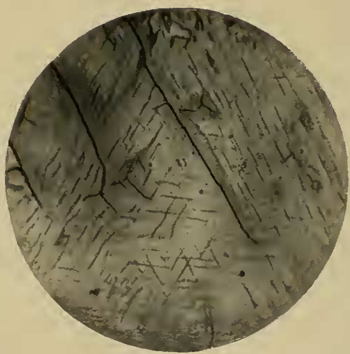

FIG. 12.

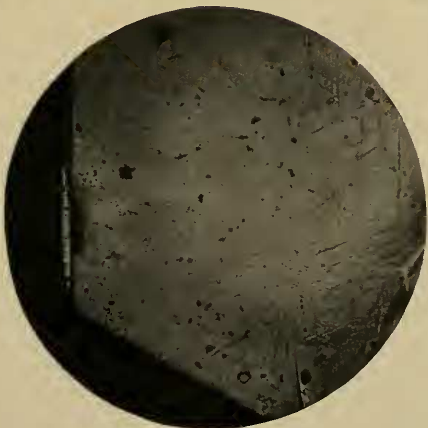

FIG. 11.

all conditions of concentration and temperature only very slightly. In one experiment with cold HCl (1 part concentrated HCl 30.5 %, sp. g. = 1.515 with 1 part water, time of exposition 7′), however, very small etch figures with sharp hexagonal outline were produced, not unlike those resulting from nitric acid. Their edges ran also parallel to the outer crystal edges. The absence of one set of parallel lines in the vicinity of that outer edge to which it was parallel was also observed on one crystal, etched with HCl. It is noteworthy that in this chemical process no noticeable gas bubbles are seen to escape.

Both the crystallographic measurements and the etch figures seem thus to prove the hexagonal nature of artificial domeykite crystals. On the following minerals, however: argentodomeykite, stibiodomeykite and mohawkite, the basal plane was so poorly developed that good, trustworthy etch figures could not be obtained. Their crystallographic system was deduced solely from the goniometric measurements.

In a recent article[1] on artificial domeykite crystals, Mr. Stevanovics considers the crystals examined by him to be orthorhombic, notwithstanding the hexagonal symmetry of his measurements, and bases his conclusions on the appearance of a cleavage after the macropinacoid, 100. A careful investigation by the present writer confirmed the cleavage noted above after three faces 60° apart. The cleavage seemed equally good after all three faces. In certain pieces cleavage fragments of perfect hexagonal outline (equilateral triangles) were produced. On the goniometer the angle between two such cleavage faces was found to be approximately 60°. The basal plane was uneven and did not permit an exact adjustment of the crystal.

The elements and forms described by Mr. Stevanovics were the following:

Orthorhombic: $a : b : c = 0.5771 : 1 : 1.026$

Forms:	*c*	*m*	*b*	*p*	*d*	*v*	*g*	*z*	*e*	*r*?	*t*?	*q*?
	001	110	010	111	021	112	011	113	023	043	041	0.5.12

with *t*, *r*, *q* rare and uncertain.

As hexagonal crystals these elements and forms become:

[1] *Zeitschr. f. Krystallographie*, Vol. xxxvii, pp. 245–246, 1903.

Element: $p_0 =$ 1.0206

$a : c_{10} = 1 : 0.8838$

$a : c_1 = 1 : 1.531$

Forms:	c	m, b	t (?)	d, p	g, v	r (?)	e, z	q (?)
Bravais......	0001	$10\bar{1}0$	$40\bar{4}1$	$20\bar{2}1$	$10\bar{1}1$	$40\bar{4}3$	$20\bar{2}3$	$50\bar{5}12$
Gdt.........	0	∞ 0	40	20	10	$\frac{4}{3}$	$\frac{2}{3}$ 0	$\frac{5}{12}$ 0

ARGENTODOMEYKITE.

The crystals of the artificial argentodomeykite belong also to the holohedral division of the hexagonal system. Four crystals only were measured, each crystal exhibiting slightly different elements, due probably to a varying percentage of silver. For the form p, 20 of the several crystals

The angle $\rho = 65° 14' \pm 29'$, $p_0 = 2.167 \pm 0.047$, in the first crystal.
$\rho = 65° 08' \pm 20'$, $p_0 = 2.158 \pm 0.032$, in the second.
$\rho = 64° 33' \pm 11'$, $p_0 = 2.101 \pm 0.017$, in the third.
$\rho = 64° 36' \pm 15'$, $p_0 = 2.106 \pm 0.024$, in the fourth.

Although the above quantities vary considerably, still they show clearly that the entrance of the silver in the domeykite crystal particle causes a change in its elements, the pyramids becoming steeper.

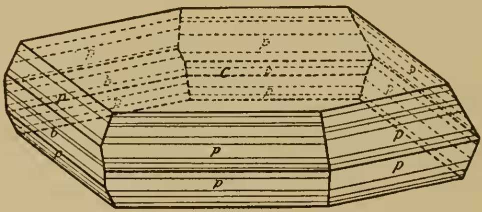

Fig. 6.

The quality of the faces of these artificial crystals was so poor that the influence of the silver in per cent. could not be determined.

Size of crystals and character of faces similar to domeykite. Of the pyramids the form p, 20 predominates, the form v, 10 occurred but once, while p, $\frac{3}{2}$ 0 was not observed. The face p, 20 frequently exhibits a slight cylindrical rounding, the axis of which runs parallel to the basal edge. Its reflexion signal is then a short light band, its bright central part indicating the position of the face. The faces are invariably striated horizontally. The different types of crystal habit are illustrated in Figs. 6 and 7 (dimensions of crystals 0.9 × 0.9 × 0.4 mm. and 1 x 0.5 × 0.4 mm.).

The external appearance of the artificial argentodomeykite resembles that of domeykite. Its color is perhaps more nearly silver-white. The crystals tarnish easily and become iridescent.

Stibiodomeykite.

The artificial products of this mineral were not suitable for goniometric measurement. The faces were without exception uneven. An examination of the various preparations with a pocket lens revealed two different types of crystal habit—the first of them tabular with the base predominating, the other faces practically undeveloped; the second long prismatic, almost arrow-shaped, the horizontally striated pyramid faces terminating either in a short point

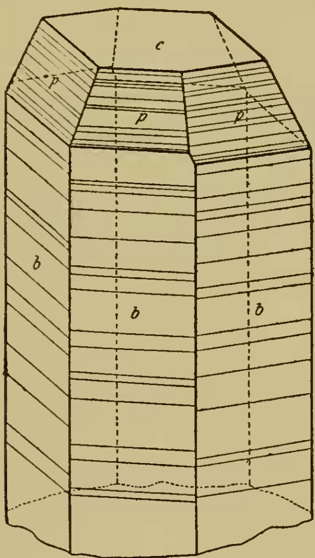

Fig. 7.

or becoming wider at the top, and resembling then an overturned bottle or inverted cone.

Color, light steel-gray. Tarnishes less readily than preceding minerals and iridescence rarely noticeable. Fracture conchoidal. H = 3–4.